Installation of a State-of-the-Art Slag Granulation Plant

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INTRODUCTION

HKM operates two blast furnaces at their Duisburg plant in the heart of Germany's Ruhr industrial region, contributing to the production of more than five million tons of steel each year. A comparison of the main features of these two furnaces is shown in **Figure 1**.

Blast Furnace	**A**	**B**
Year of construction	1973	1981
Last relining	1998	2000
Hearth diameter	10.3 m	11.0 m
Effective capacity	2,449 m^3	2,824 m^3
Charging equipment	Double bell with moveable armour	Rotating chute
Top pressure	2.8 bar	2.8 bar
Blast temperature	1,270 ^{o}C	1,320 ^{o}C
Tuyeres	30	30
Tapping holes	2	2
Capacity	2.5 million t/a	2.7 million t/a
Hot blast stoves		
Number	3	3
Dedusting		
Top gas dedusting	Ring-slot washer	Radial-flow washer
Casting-house d.	EP	EP
Slag removal		
Type	Granulation AJO	Granulation VAI-RASA

Figure 1: Comparison of blast furnaces at HKM's Duisburg plant

This paper deals with the contract to supply a granulation facility for blast furnace 'B'. The installation of the plant at Blast Furnace 'B' was required in order to complement the already existing facility at blast furnace 'A'. Typical performance of Blast Furnace 'B' over the last few years is indicated in **Figures 2** and **3**.

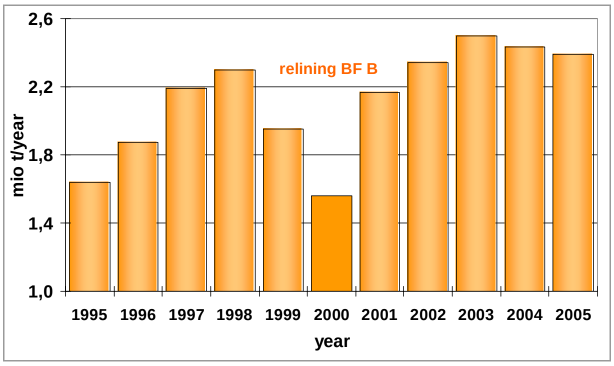

Figure 2: HKM's blast furnace 'B' annual production

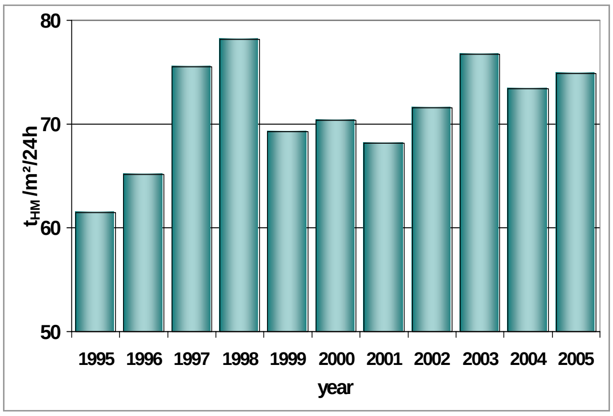

Figure 3: Productivity, hearth area productivity of blast furnace 'B'

Based on the typical performance of the blast furnace and the expected slag type and volumesm shown above, the plant requirements were defined by HKM. The actual slag quality for the period is shown in **Figure 4**.

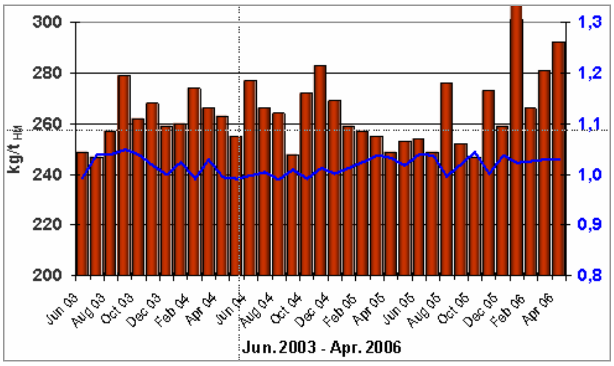

Figure 4: Slag volume and basicity, BF B

Siemens VAI have previously worked with steel producers around the world in the design and development of slag granulation systems, and through a license agreement with the RASA Corporation of Japan they have further increased access to the latest plan designs. Experience has included gravel dewatering, slurry pumping and screw/mesh rolls systems.

At the time of the proposal for HKM, the favoured solution for producing a high quality marketable granulated slag product consisted of primary dewatering by a screw conveyor followed by secondary dewatering using a mesh roll filter.

Because of environmental reasons, the gaseous emissions had to be reduced. That's why we had to engineer a fully-contained condensation system.

DESIGN

The project to design, supply, erect and commission a slag granulation plant at the HKM blast furnace 'B' using the RASA process technology was awarded by HKM in early 2002 based on a consortium of two Siemens VAI group companies, and led by Deutsche VAI (DVAI) based in Düsseldorf. DVAI were responsible for the overall project management, engineering, supply, installation and construction, with the basic system design and key component supply being carried out by Siemens VAI.

The initial design concept was based on the successful plants built by Siemens VAI at the POSCO Gwangyang Works and at China Steel's Kaohsiung no.4 blast furnace. As indicated in **Figure 5**, after the slag is granulated at the spray box, primary dewatering is carried out using a screw conveyor. This conveyor removes the product granulate (~97% of slag input) whilst leaving the majority of the fine slag wool in suspension. The product granulate with about 25% water content is transported by conveyor to the final product dewatering area. The water from the slag basin is then further cleaned by passing it through a mesh roll filter which allows for the removal of the slag wool. The use of the screw conveyor for the primary separation process allows the plant to operate extremely well during periods of slag surge with a high availability.

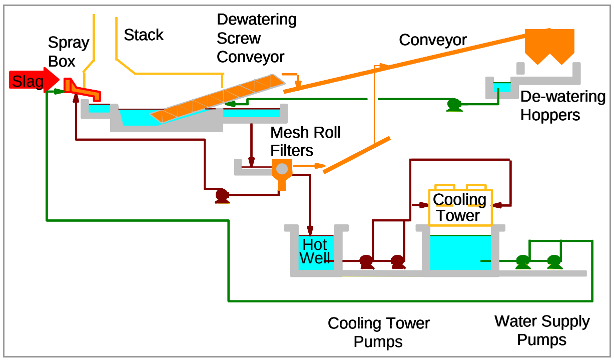

Figure 5: RASA-VAI wet slag granulation system concept for China Steel's Kaohsiung no.4 blast furnace

This basic concept was the starting point for the design of the HKM plant at Duisburg, however there were a number of design changes which reflected the different operational experience and maintenance philosophy of HKM engineers and the local environmental regulations. Also, because of the existing blast furnace layout, it was necessary to engineer a new plant arrangement which fitted within the restricted confines of the hot metal tracks without causing any interruption to the flow of hot metal.

The new features that required incorporating into the overall design were:

- The end section of the common slag runner in copper
- An enclosed stack to prevent H_2S and SO_2 emissions
- A variable flow, constant pressure spray box with focused jets to optimize granulate quality
- Variable Voltage Variable Frequency drives on all the main pumps, none of which incorporated standby drives
- A single mesh roll filter of increased capacity, specifically developed for this plant

Copper Slag Outlet

The existing casthouse slag runner system required extending in order to provide the central feed to the slag granulation system, and the last four metres of the new common section were designed to be a low maintenance copper stave. The design of this copper slag runner was based on the stave concept from blast furnace shell cooling systems. The arrangement was developed using finite element analysis (ANSYS) modelling, as shown in **Figure 6** below, and consisted of a base stave on the bottom and two side staves. The water cooling

channels were designed in order to obtain the formation of a solid slag layer over the length of the runner, thus reducing the need for maintenance of the runner section immediately before the slag spray box.

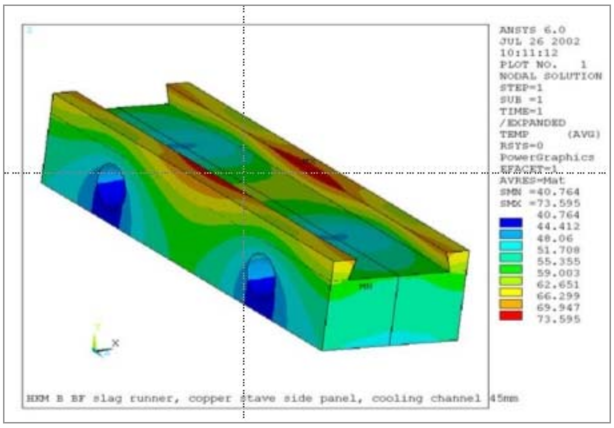

Figure 6: Thermal analysis of copper stave for slag runner

Condensation Tower

As previously discussed, the original concept of granulation systems allowed atmospheric emissions from the stack and these can contain a relatively high H_2S content, approximately 200ppm. Therefore, an additional plant was required in order to greatly reduce this value and **Figure 7** below shows the concept for the condensation system as developed with HKM.

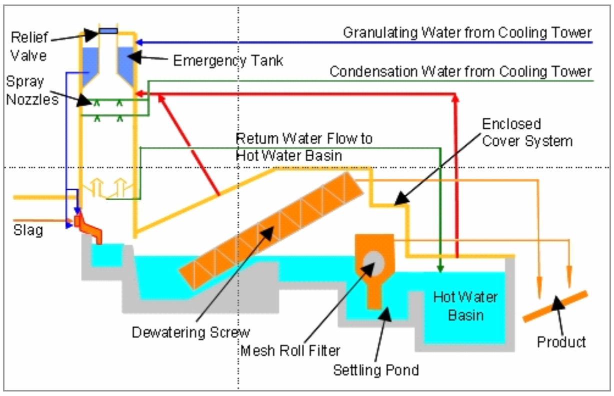

Figure 7: Basic design concept for condensation system

The emission requirements meant that all equipment had to be enclosed and thus the screw basin, settling pond and hotwell were all provided with removable covers. The settling pond was used for tertiary separation of the product and was incorporated in this design upon the request of HKM. The cover to the settling pond utilized hydraulic actuation in order to reduce downtime during cleaning operations. Most condensation systems rely on restricting the entrainment of air with the slag as it runs into the spray box slag runner and on creating a closed system. A completely closed system is not possible with the RASA-VAI system due to the addition of air via nozzles on the mesh roll filter which allow separation of the product from the filter mesh. Therefore, by arrangement of the system vapour flows, the sulphur reactions are controlled in order to prevent any H_2S emission with the product or in the cooling tower.

The water required for the condensation system runs as a separate line from the cold water basin to the tower itself. Variable flow control of the water to the tower ensures complete coverage of the spray tower through the four rows of spray heads. The return water is then collected in the base of the tower and gravity-fed to the hot water basin where it mixes with the returned granulating water from the screw and mesh roll filter prior to being pumped through the cooling tower.

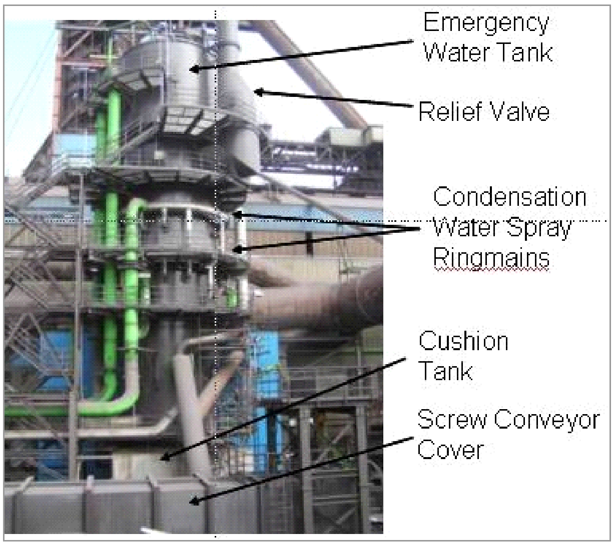

Figure 8: View of condensation tower

Variable Flow Spray Box

At HKM, in order to maintain an approximately fixed water-to-slag ratio, the spray box orifice was designed to be variable. The automated control of the spray box opening, used in conjunction with the supply of the granulating water at a constant pressure, enabled good control over the flow rate, and by accurately tuning the process control system, a water-to-slag ratio of a minimum of 5 to 1 was consistently obtained.

VVVF Drives

After discussions with HKM on their previous experiences, it was decided that redundancy of pumps was not required. Therefore, single pumps of 100% capacity were utilized and the variable water flow rates necessary to maintain a fixed water-to-slag ratio were obtained using VVVF drives, thus giving additional gains in power consumption when operated at flow rates below the design rating.

Single Mesh Roll Filter

Figure 9 illustrates the basic arrangement of the drum filter.

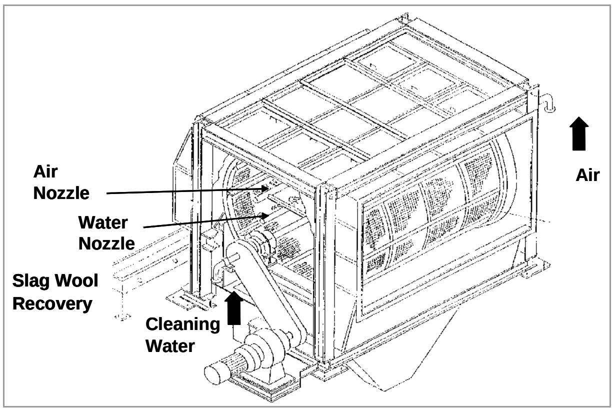

Figure 9: Mesh roll filter

At HKM, with the variable water flow rates, it was decided to provide a single larger filter (DF6 type). The overall capacity of the DF6 is similar to two DF4s but requires excellent control to avoid overflow directly to the settling pond.

INSTALLATION & COMMISSIONING

After a rapid design phase starting in February 2002, the start of the civil phase of construction occurred towards the end of August 2002 with mechanical erection starting early in the beginning of 2003. Cold commissioning began in May 2003, giving an overall project duration of 16 months to start-up.

Figure 10: Installation of the screw Conveyor

Commissioning went well with only minor issues identified at the sequence control. This achievement was testament to the quality and endeavour of the site team and, as during construction, a close cooperation with the HKM personnel. The commissioning of the water system control logic was extremely important in achieving a balance of the water flows through the various basins utilizing the pump VVVF drives. The time invested in obtaining consistent control reduced the likelihood of control trips during initial operation and thus enabled the plant availability to be maintained at a high level right from the beginning of commercial operation.

START-UP

The first slag tap was taken on 17th June 2003 and the initial hot commissioning period was relatively uneventful. **Figure 11** below, shows the first product granulate emerging from the screw conveyor outlet, which was immediately noted to be of high quality. The main target of this period was to refine the instrumentation feedback in order to improve the control system prediction of the slag flow rate. This calculated slag flow rate was then used to control the spray box water flow rate in order to maintain a steady water-to-slag ratio and thus good quality granulate of the correct particle size. Some control refinements made to further improve the system included adding a rate of temperature change factor in order to ensure that water flow increases led any slag flow increases. The sequence logic functioned very successfully and a balance of the hot water flows was rapidly achieved, allowing fine tuning of the level control to be carried out.

Figure 11: Granulate from the first slag cast as it is discharged from the screw conveyor outlet

The month-long performance test was successfully completed on 12th September 2003. During the test period, the guaranteed availability of more than 97% was comfortably achieved with a power consumption of less than 10 kWh per ton of slag. The product granulate had a glassy content greater than 95% and a grain distribution of more than 95% between 0 and 3 mm.

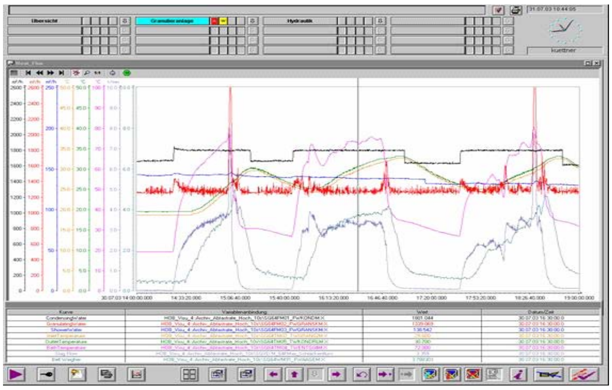

Figure 12: Operating data from the start-up period

Figure 12 is a trend of operating data from three casts carried out on the 30th July 2003. It shows the general repeatability of the system, with maximum bath water temperatures attained of approximately 75 °C with slag rates of the order of 4 t/min.

MAINTENANCE & OPERATION

After completion of the performance tests, HKM assumed responsibility for the plant operation with continued support from the Siemens VAI organization. The first 18 months of operation have demonstrated the robustness of the plant equipment. This philosophy included ensuring all parts of the system were easily accessible for maintenance, reducing the number of moving parts in the water system and including ceramic or stainless steel parts where necessary in order to reduce the interruptions due to wear.

The latest development of the dewatering screw conveyor, incorporating the design modifications from previous installations and an improved lifting device, has proven very successful at HKM. The concept of being able to handle large quantities of slag with minimal maintenance has been ably demonstrated, with the design capable of accepting short-term peaks of over 10 t/min.

The continued operation of the plant is indicated in **Figure 13,** where it should be noted that no adjustments have been made for periods of low demand in the market and external plant maintenance, which have occasionally led to the granulation facility being under employed.

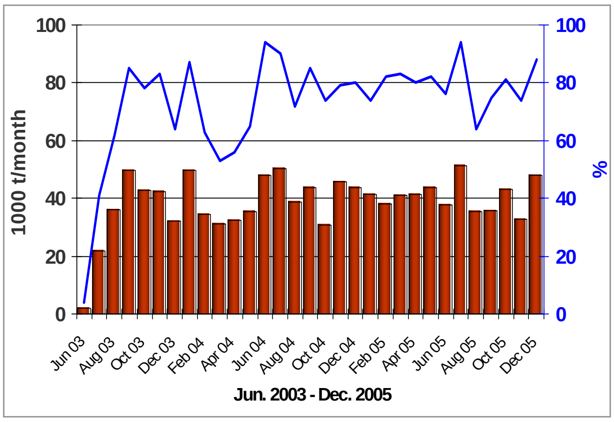

Figure 13: Slag granulate production since initial operation

CONCLUSION

The successful start-up of the slag granulation plant was due to the good co-operation established between all parties during the course of the project. The granulated slag product is consistently of a high quality. The granulation plant achieved the requirements to continue the reductions in the level of H_2S emissions and also its current operation at high availabilities demonstrates the robustness of the screw dewatering process.

CURRICULUM VITAE

Mr. Juergen Gertz completed his Dipl.-Ing. degree at the University of Duisburg in 1981. In the same year, he joined Krupp Stahl AG and began working in the blast furnace department in Rheinhausen as a process engineer. In 1993, he changed to Krupp Hoesch Stahl AG Dortmund and was responsible for the production site. Since 2001, he has been working as a division manager in the blast furnace production department of HKM. The last main projects were the installation of natural gas injection equipment and slag granulation at Blast Furnace "B".